Utilizing a Trauma Systems Approach to Benchmark and Improve Combat Casualty Care

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Background: Derived from the necessity to improve the outcomes of soldiers injured on the battlefield, the U.S. military forces developed and implemented the Joint Theater Trauma System (JTTS) and the Joint Theater Trauma Registry based on U.S. civilian trauma system models. The purpose of this analysis was to develop battlefield injury outcome benchmark metrics and to evaluate the impact of JTTS-driven performance improvement interventions.

Methods: To quantify these achievements, the Joint Theater Trauma Registry captured mechanistic, physiologic, diagnostic, therapeutic, and outcome data on 18,377 injured patients from January 2004 to May 2008 for analysis. Benchmarks were developed and statistically validated by using control chart methodology.

Results: The majority (66.4%) of battlefield wounds were penetrating mechanism, 23.3% of all patients had an Injury Severity Score of ≥16, 21.8% had a base deficit of ≥5, 30.5% of patients required blood, and 6.8% required massive transfusion (≥10 units red blood cell per 24 hours). In this severely injured population from the battlefield, the JTTS developed several pertinent benchmark metrics to assess quality of care associated with postinjury complications and mortality. The implementation of 27 JTTS-developed evidenced-based clinical practice guidelines and an improved information dissemination process was associated with a decrease in aggregate postinjury complications by 54%.

Conclusions: Despite the numerous challenges of a global trauma system, the JTTS has set the standard for trauma care on the modern battlefield utilizing evidence-based medicine. The development of injury care benchmarks enhanced the evolution of the combat casualty care performance improvement process within the trauma system.

Key Words: Benchmark, Trauma system, Trauma, Injury, Combat casualty care.

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In the late 1980s, the U.S. Department of Veterans Affairs (VA) faced a barrage of public and governmental criticism over the quality of surgical care in its 133 designated hospitals. At specific issue were operative mortality rates and the perception of substandard care in comparison to national private sector norms. In response, Congress passed U.S. Public Law 99–166 mandating that the VA report its surgical risk-adjusted outcomes annually in comparison with normalized national values. However, risk-adjusted surgical outcomes and national averages did not exist at the time. During the next several years, the VA system collected data and modeled outcome analysis of which was born the National Surgical Quality Improvement Project (NSQIP). Between 1991 and 2001, the VA demonstrated a 27% decline in postoperative mortality, a 45% decline in postoperative morbidity, and a median postoperative length of stay that declined from 9 days to 4 days.[1–5] Of note during this period, volume and complexity of major surgery and risk profiles of patients were unchanged. Because of the success of this performance improvement program, the American College of Surgeons (ACS) adopted NSQIP to benchmark the quality of surgical care in 2004. As a natural progression, the ACS Committee on Trauma developed the Trauma Quality Improvement Program (TQIP), whose fundamental aim is to provide risk-adjusted benchmarking of designated/verified trauma centers to track outcomes and improve patient care. The objectives of these efforts are to enhance trauma data collection and benchmark outcomes and to identify and improve the process of trauma care.

On the basis of these successes and built on the foundations of the ACS Committee on Trauma document, "Optimal Resources for the Care of the Injured Patient," the Joint Theater Trauma System (JTTS) developed metrics to guide medical practice and medical command decision making with respect to resource allocation, casualty trends, and trauma care outcomes.[6] We hypothesized that performance improvement initiatives implemented by the JTTS had a demonstrable positive effect on battlefield injury care. Benchmark metrics were developed to validate the impact of the JTTS to improve combat casualty care.

MATERIALS AND METHODS

To benchmark combat casualty care, the Joint Theater Trauma Registry (JTTR) captured mechanistic, physiologic,

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diagnostic, therapeutic, and outcome data on 18,377 injured patients from January 2004 to May 2008 for analysis. Three outcome measures were chosen for analysis: mortality after transfusion of 1 unit to 9 units of red blood cells (RBCs), mortality after transfusion of ≥10 units RBCs, and aggregate complications. Control chart methodology was used to establish normative references for each variable studied. Using this statistical technique based on probability distributions, each variable had a calculated mean, upper control limit, and lower control limit which represented the central tendency and the range of natural variation of plotted values.

Within the control chart graphs, the upper control limits were denoted as 3 SDs from the mean. Interpretation of values in the "tails" or outside the control limits is similar to that of conventional hypothesis tests; i.e., these values were statistically significant indications that the process is producing different outcomes. Of note, lower control limits were not depicted for variables in which negative values were not valid with respect to the meaning of the variable being measured. To aid in interpretation, we defined sentinel events as individual peaks for a single data point in a series. Mean shifts were identified as a series of eight consecutive values residing on the same side of the mean or center line. Trends were defined as six consecutive increasing or decreasing values.

RESULTS

The majority (66.4%) of battlefield wounds were penetrating mechanism, 23.3% of all patients had an Injury Severity Score ≥16, 21.8% had a base deficit ≥5, 30.5% of patients required blood, and 6.8% required massive transfusion (≥10 unit RBC per 24 hour). In this severely injured population of battlefield injuries, the JTTS developed several pertinent benchmark metrics to assess quality of care associated with postinjury complications and mortality.

Figure 1 demonstrates a mean mortality of 16.4% in injured casualties receiving 1 unit to 9 units of RBCs. In patients receiving ≥10 units of RBCs, the composite mortality mean was 20.8%, as shown in Figure 2. Of note, monthly mortality after mid-2006 was consistently below the normative control level and represented a baseline shift (horizontal circle). Postinjury complication events are characterized in aggregate in Figure 3. There were three discrete mean value sets within the complication analysis.

DISCUSSION

In general, benchmarking is the process of investigation and discovery that emphasizes evidence-based best practices that produce superior performance when adapted and implemented within an organization. Benchmark metrics have garnered widespread acceptance in surgery and trauma within the United States as a result of the successes of the NSQIP and the TQIP.[1–5,7–14]

The vision for initiating a trauma system of care for the battlefield is to ensure that each soldier, sailor, airman, or marine injured on the battlefield has the optimal chance for survival and ultimately for functional recovery.[15,16] We hypothesized that performance improvement initiatives implemented by the trauma system had a demonstrable positive effect on battlefield injury care. The natural progression of this theme was the development of injury care benchmarks both realistic and relevant to the combat environment to validate the impact of the JTTS to improve combat casualty care.

For this analysis, we chose to concentrate on the mortality associated with blood transfusion and the complication rate after battlefield injury. We chose these initial benchmarks because of the significant amount of data available within the JTTR to quantify these metrics. The most substantial pathology responsible for mortality on the battlefield is

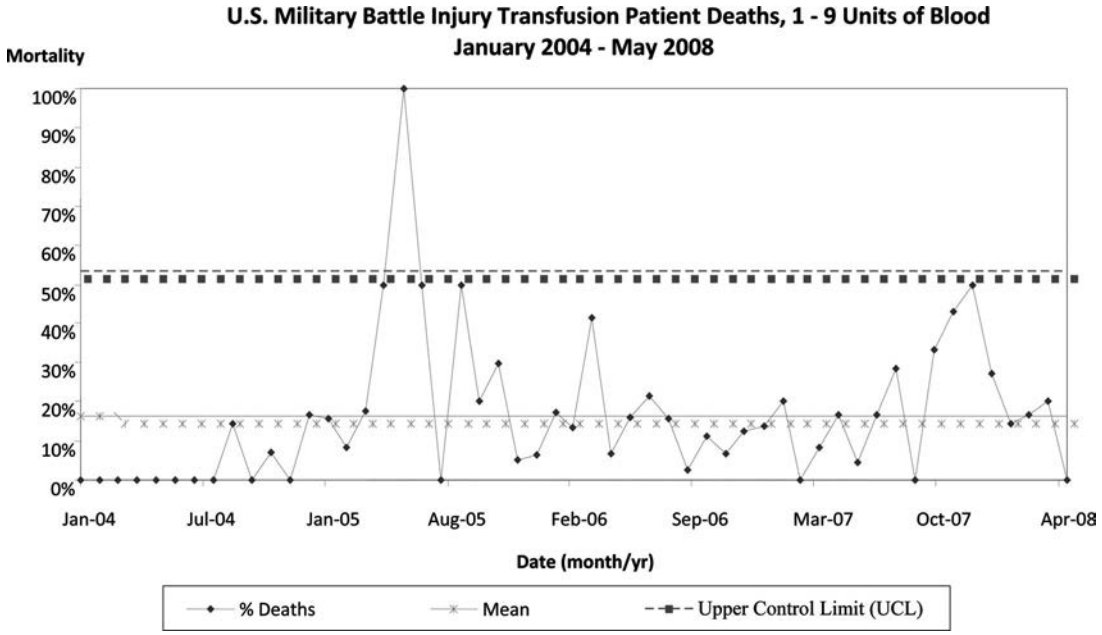

Figure. 1. Battlefield injury mortality, 1 unit to 9 units of red blood cells.

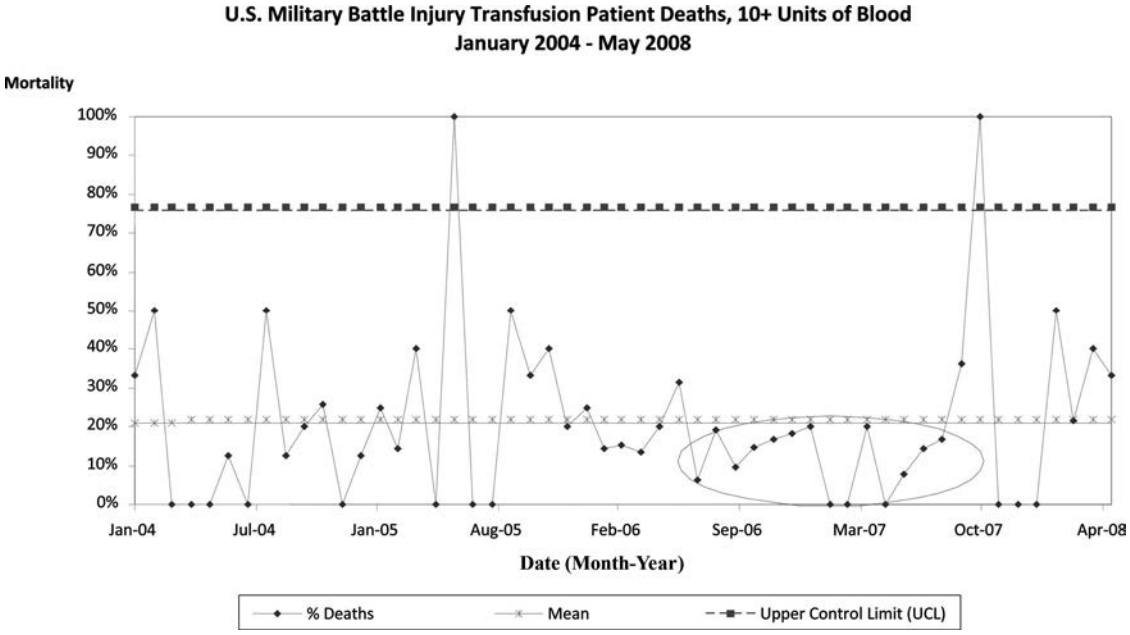

Figure. 2. Battlefield injury mortality >10 units of red blood cells.

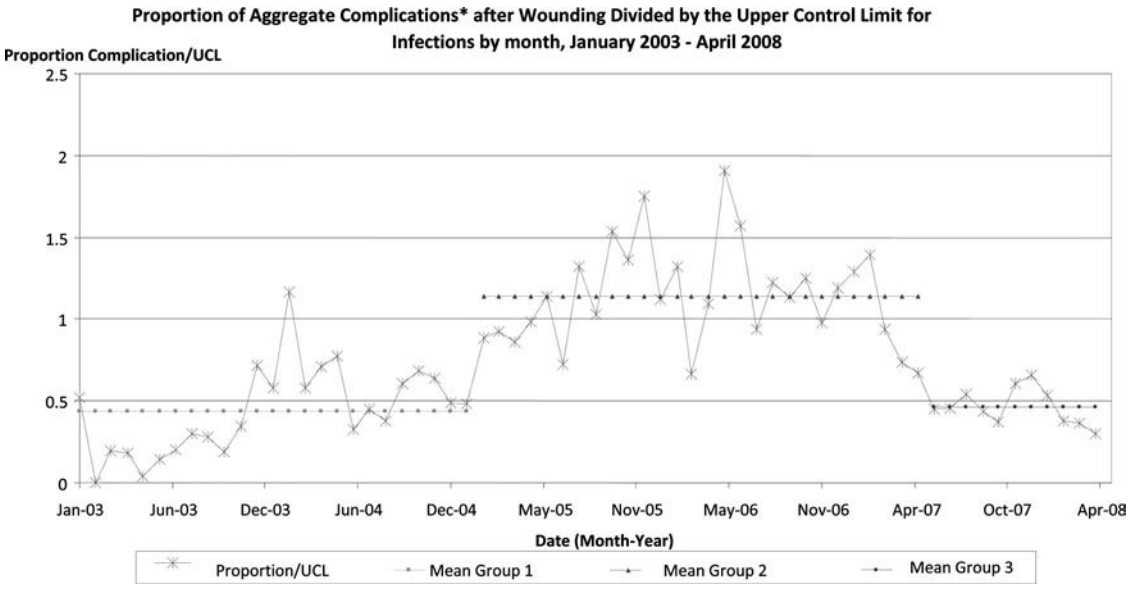

Figure. 3. Battlefield injury aggregate complications.

hemorrhage.[17,18] In the civilian trauma environment, hemorrhage also accounts for the largest proportion of early mortality,[19] When one considers those injuries that are potentially survivable with prompt and aggressive therapy, then the impact of hemorrhage on battlefield injury outcomes becomes even more significant.[18] Post-traumatic hemorrhage is not readily measured; however, the magnitude of RBC transfusion, packed RBCs, and whole blood required to resuscitate the combat casualty is a quantifiable surrogate. We analyzed two levels of RBC transfusion that correlated with nonmassive and massive transfusion. Massive transfusion was characterized as ≥10 units RBCs within a 24-hour period. Analysis of the nonmassive transfusion data demonstrated that mortality outcomes, with the exception of a single outlier, consistently fell within range of the normative reference, the 16.4% mean for the series. The single outlier correlated to a month with just two casualties requiring 1 unit to 9 units of blood, but both died from severe traumatic brain injury. Also, notable within this benchmark metric was the lack of demonstrable change during the time period associated with the evolution of the trauma system and systemic dissemination performance improvement measures. On the other hand, when benchmarking the massive transfusion mortality outcome data, although the mean for the entire time continuum was 20.8%, there was a notable decrease

in mortality after mid-2006, as noted by the baseline shift. With few exceptions, mortality fell within 1 SD from the mean for the time series. This benchmark indicates sustained performance. These outcomes have been substantiated in several independent analyses of combat damage-control resuscitation.[20,21] This increase in survival of the most seriously injured casualties corresponded to multiple performance improvement initiatives of the JTTS, including the dissemination of multiple clinical performance guidelines; specifically, the damage-control resuscitation and whole blood utilization algorithms. In addition, during the same time period in mid-2006, the JTTS initiated weekly global patient care teleconferences and a more broad system issue teleconference held on a monthly basis. These two information portals served to disseminate real-time evidence-based analysis to injury care providers in theater. The identification of clinical benchmarks and the dissemination of clinical best practices were the hallmarks of the success of the NSQIP and TQIP strategies.[1] To exemplify the value of this analysis, a thorough investigation of mortality spikes in May 2005 and September 2007 was notable for only one massive transfusion patient within the database for those months; and in both circumstances, the result was mortality. Therefore, the apparent change in mortality rate was a bias of low patient numbers recorded within those two time periods. With that being said, this subanalysis demonstrated the value of longitudinal internal benchmarking by substantiating the value of performance improvement measures and having the capacity to evaluate and separate sampling artifacts.

Because the postinjury died of wounds threshold on the battlefield has neared that of civilian trauma centers, we also chose to assess significant nonmortality outcomes with relevance to the combat theater as a part of the benchmarking initiative. Multiple system organ failure, as a sequelae of injury or complications, is the most significant etiology of morbidity and late postinjury mortality.[22] A concomitant 54% decline in the number of aggregate complications incurred by those surviving their battlefield wounds corresponded to the systemic dissemination of evidence-based practices. Current studies are ongoing to evaluate the rate of multiple organ dysfunction during the conflict. Once these data are available, it will be instructive to refer the rate of organ dysfunction against the complication rates in this analysis to evaluate the impact of complications and develop mitigation strategies for combat casualty care.

This study was a descriptive analysis and may have several inherent limitations. Probably, the most substantial limitation may be a predilection for selection bias, because the time course for the analyzed period corresponded to the gross evolution of the JTTS. Consequently, the characteristics of the data reported changed during the maturation process of the trauma system. With the inception of the JTTS and JTTR, there was a concentration on injury care within the combat theater and a likelihood of early underreporting of adverse sequelae and complications along the evacuation chain, particularly because the registry and abstraction capabilities of those levels developed later in the process. We postulate that the reason that the complication rate demonstrated early in the conflict was relatively low which was indeed an artifact of this selection bias.

There is a tremendous potential for benchmarking morbidity and mortality after injury in combat. Information from these analyses may identify areas of care that require additional emphasis, which may be even more important in the resource-constrained battlefield environment. It is absolutely essential to note that this process should be attributive, but not punitive, to maintain the transparency and integrity of the process.

CONCLUSIONS

During the course of the last 5 years, the military has developed an effective regionalization of trauma care after injury on the battlefield that has become the "standard of care" on the battlefield. Along with this evolution has come more effective and efficient techniques for capturing and analyzing trauma data for disseminating real-time data-driven quality improvement measures. The current effort focused on internal clinical benchmarks. A next step for the future of the JTTS will be to develop external benchmarking standards to evaluate and further improve the outcomes after battlefield injury. Future studies are necessary to evaluate the impact of benchmarking at the system structure and process.

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DISCUSSION

Dr. Bryan A. Cotton (University of Texas Health Science Center at Houston): I would like to thank ATACCC and its membership for the opportunity to discuss this manuscript and for the invitation to attend this year's meeting. Dr. Eastridge and colleagues have evaluated the Joint Theater Trauma System's Registry in an attempt to construct a database for benchmarking combat casualty care. Benchmarking in the surgical and trauma arena describes a process of identification and application of "best practices" which are derived from evidence-based guidelines. Intra-institutional and inter-institutional clinical management and the associated outcomes are then tracked through performance improvement measures. Internal benchmarking is the used to monitor an institution or group's performance longitudinally over time in hopes of demonstrating improvement of care from one time period to the next. External benchmarking, however, is used compare one an institution's performance against an established standard reference of high-volume, "high performance" institutions. From what I can tell from the manuscript, the authors have attempted to perform the former. However, the true value and application of this benchmarking process, one matured, would (in my opinion) be the ability to establish a high-performing standard by which the practices of these centers could serve as guidelines for improving care and outcomes at "low-performance" combat support hospitals. Given the value of this aggregated registry, my first question for the authors is do they have plans to take this internal benchmarking process to an external bench marking standard and use this to evaluate and improve the outcomes at low-performance hospitals?

Though in-hospital mortality is a traditional outcome used to benchmark performance among, greater emphasis is being placed on using complications as benchmarking metrics as many of these are associated with high quality evidence-based guidelines. As well, morbidity rates poorly correlate with observed mortality rates. As such, my second question for the authors is do they have plans to utilize complication rates (other than ventilator-associated pneumonia) in determining benchmarking success rather than the more crude analysis of observed to expected mortality rates?

As the authors are fully aware, the quality of data input determines the quality of data output. Therefore, my next question for the authors is has the Joint Theater Registry been validated with respect to ensuring correct identification and input of numerator data?

Several techniques have been described for handling missing data in large registry databases. One approach is to simply exclude variables or patients with missing data. However, this excludes potentially critical data and may severely affect the validity of the data set and its results and interpretations. To address this, several imputation techniques have been described to generate values for observations with missing data. So, my final question for the authors is with respect to the multiple imputation application for missing data, did the authors utilize a Monte-Carlo simulation for these variables or was another methodology employed? Will they please briefly describe their methods?

I would once again like to thank ATACCC for the opportunity to discuss this manuscript.

Dr. Brian J. Eastridge (U.S. Army Institute of Surgical Research): My coauthors and I would like to thank Dr. Cotton for his insightful review of our manuscript. To answer the first question with regard to external benchmarking, the purpose of developing and validating a combat casualty care benchmark process was to ascribe performance metrics in order to set the quality "bar" for deployed trauma care. With that being said, this technique could certainly be utilized to identify deficiencies in "low performers," which could then be remediated with standard performance improvement modalities.

Dr. Cotton makes a very astute observation about the limitations of many past studies of trauma outcome benchmarks in that mortality has been used as the singular outcome variable. More recent evidence suggests that complications may be more reflective of quality of care rendered. Consequently, we chose to develop aggregate complication rate as one of the central metrics in this analysis. We hope to stratify individual complication rates in subsequent analyses.

Data quality and integrity is a central focus in the aggregation and dissemination of JTTR data. To this end, data entry into the registry is tightly controlled. Deployed trauma providers undergo an intensive pre-deployment training program in data management and migration. A core staff of certified coders enters data at a central site at Fort Sam Houston. In addition, we have a periodic data quality audit to ensure the highest quality of data possible within the registry.

Missing data was specifically not included or imputed in the analysis presented here today. However, in subsequent benchmark analyses, which we hope to publish in the future, we found the Monte-Carlo simulation technique to be very useful in imputing absent physiologic variables necessary to model TRISS-based observed/expected mortality ratios.

In conclusion, we would like to thank Dr. Cotton for his comments and the ATACCC Program Committee for allowing us the privilege of presenting our data.

